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METHODS FOR FIELD STUDY OF INDUSTRIAL FATIGUE.[1]

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Field investigation into industrial fatigue means investigation carried out in the factory itself, where fatigue is produced by ordinary work, as contrasted with experiments carried on in the laboratory, where fatigue is produced artificially and "ad hoc." These field investigations fall into two classes, investigations which measure ordinary natural fatigue by means of artificial "tests," such as the tests of reaction time or tests of sense acuity, carried out notably by Prof. Stanley Kent under the British Home Office and described in his two interim reports of 1915 and 1916, and investigations which measure fatigue by the ordinary events of industrial life, such as output (quantity and quality), accidents, power consumption, sickness, labor turnover. The most usual measure to take is that of quantity of output, wherever this does not depend exclusively on the speed of the machine. The data of the investigator are here either found ready for him in factory records kept for purposes of checking wages or measuring efficiency, or the investigator may observe and record the industrial processes himself. The output measure has been used recently by the British Health of Munition Workers Committee. Dr. Vernon, in Memoranda 12 and 18, has compared the output of the same individual workers in the same factory under different hourly schedules, i. e., he has compared the output per hour in a 70-hour working week against the output per hour in a 60-hour week. This was also the method pursued by Dr. Abbé in his famous experiment at the Zeiss Optical Works in reducing hours from 9 to 8 per day. Again in their interim report the British Health of Munition Workers Committee compared the output per hour on night work against the output per hour of the same workers when on the day shift, and they also compared the output per hour under different incentives.

[1] Read before the Section on Industrial Hygiene of the American Public Health Association, Washington, D. C., Oct. 19, 1917.

Now, all these investigations have compared the output of a given number of individuals before with the output after a change. Yet changes in hours are very distasteful to most factory owners. They require thought and involve many incidental rearrangements. The field for the "before and after" comparison is therefore strictly limited, and what I wish to put before you to-day is a method of testing fatigue which shall not depend immediately on any change in factory schedules.

This test may be called that of the "hourly output curve." Curiously enough, it was first used on a large scale by the United States Government in the report on Women and Child Wage Earners[1] (1910–1912). In volume 11 a table is given stating the output from stamping presses for every hour of the day. Twenty-three machines were observed from 1 to 7 days each and the output for each hour, (8 to 9, 9 to 10, etc.) added up in a total, 10 working hours being compared. Similarly in the Federal report on the Conditions of Employment in the Iron and Steel Industry[2] (1911) the number of blows from two Bessemer converters is given for 8 months for every hour of two 12-hour shifts.

Fatigue consists in a diminution of activity that is itself caused by activity. As activity proceeds activity falls, and the theory is that a comparison of the output of consecutive hours will show exactly to what extent the unrelaxed tension of activity will result in fatigue toward the end of a spell and toward the end of the working day, and exactly how far rest pauses, meal intervals, and a night's sleep will allow human capacity to gain recovery.

But it was peculiarly unfortunate that the two operations chosen by the Federal Government were of a nature not yielding definite evidence of fatigue. Work on a stamping press is extremely monotonous, and only subjectively, not objectively, tiring, while in the operation of the Bessemer converter, numerous pauses allowing for recuperation occur in the work. Between every blow the men have to wait for the completion of the material process. The result in both cases was a straight line of output throughout the day instead of a falling curve

In collecting material for the British Association Committee on Fatigue from the Economic Standpoint (1915) I obtained several output curves which differed radically from those collected by the Federal Government. The operations I chose consisted mainly in soldering by hand or in labeling biscuit tins, work requiring a certain degree of attentiveness and coordination and capable of being carried on without any pauses whatever. Comparing the different hours of the spell, a curve was obtained not very unlike the fatigue curve yielded by the contractions of a continuously stimulated muscle.

The Federal Government was discouraged by the lack of any signs of fatigue in the curves they collected, and this discouragement seems

[1] 61st Cong., 2d Sess., Doc. 645. [2] 62d Cong., 1st Sess., Doc. 110, Vol. IV.

to have spread to investigations elsewhere. Nevertheless, there seem to me to be some very good reasons why the hourly output tests should be developed and extended.

First of all, the record of output is usually easy to secure every hour. Foremen often keep it for their own benefit in estimating at any given time how the day's work is progressing. Often also there are automatic registers attached to machines to record each unit of output as on a cyclometer, and the total attained each hour may be read off at a glance.

Secondly, the output curve can be accompanied by curves in other very significant events of factory life. I refer to accidents and to the consumption of power. Just as output can be plotted from hour to hour, so can the number of accidents occuring in any factory and the amount of electrical power consumed. And with these latter tests the evidence of fatigue can not be isolated except by hourly curves. It gives no indication of fatigue to compare the rate of accidents for the whole factory during long periods under different schedules, since the rate of accidents depends so largely on the type of machine used and the experience of the workers, and these factors vary enormously at different periods. Further, in the investigations into output made hitherto, the same workers were selected for comparison before and after the change in hours, but it is impossible to do this in the case of accidents, since such selected workers may never have any accidents at all. Accidents must always be studied over the factory as a whole. Similarly with power consumption, it is very seldom that a factory keeps any records of the power consumed on certain machines or by certain special workers. The record has to be made for the factory as a whole, and with power records as with accidents it is always hard to keep all the disturbing factors constant where different and often far-distant periods are compared.

The accident curve for different hours of the working day, it is true, has often been rejected as an index of fatigue, owing to the curve showing a peak one hour from the end, rather than at the end of the spell. Why there should be a drop in the last hour it is difficult to explain. My own theory is that the anticipation of a break in his work and of food and rest makes the worker more alert and he becomes more alive to the dangers in his surroundings. But whatever the theory, an analysis of the circumstances of accidents will show a surprisingly high percentage of occurrences which the injured man could have avoided either by a quick reaction to danger or by more attention or better coordination. Accidents due purely to mechanical causes are usually not more than 5 or 10 per cent of the whole number. In my opinion, therefore, a rise in accidents must form an admirable

measure of fatigue, particularly of a psychological fatigue affecting attention and alertness rather than rapidity of motion.

There is, however, one element in the accident curve that leads to confusion. It is obvious that the more frequently a man's hands pass certain danger points in a given period of time, the more liable are accidents to occur; thus the accident curve depends partly on the worker's speed of production and will tend to rise as output is increased. To this extent, a rise in accidents will measure a rise in working capacity and not a fall. It is necessary, therefore, to eliminate this factor in the accident curve and to correct the figures to some standard output. But accidents, as we have said before, can be measured only over the whole factory and to obtain a measure of output for the whole factory also with all its varying operations and productive and nonproductive duties, is practically impossible. In this dilemma the curve of power consumption comes to our aid. Wherever, as is usually the case, the machinery and the workman jointly combine in setting the pace, it is a curve corresponding roughly to the output and yet it is obtained for the whole factory. If therefore the number of accidents per hour be divided by the amount of power consumed each hour, we shall get the curve representing the worker's loss of capacity in attention and alertness quite irrespective of the amount of work he is doing. It is this composite curve together with the curve of output described above that may yield one of the most nearly perfect measures of fatigue in the factory.

A third advantage of the hourly curve is the subtle distinction it brings out between the fatiguing effect of different types of work and possibly of different types of conditions also. Dr. Lee was able to demonstrate that monotonous work, work requiring attention, and work involving muscular strain, might yield several different shapes of curves. Unless the change of hours in a factory is very frequent the "before-and-after" comparison does not yield more than one or two combinations. It is the great number of readings composing the curve, usually 10 a day, that renders possible a more subtle analysis.

I can not close honestly without admitting one disadvantage to the hourly curve method. In their practical application the results of the curve do not point so directly to any one policy as the "before-and-after" type of investigation. The curve is obtained under one factory schedule. It is not in itself a comparison of two different schedules one of which can be declared superior to the other. If an output or power consumption curve should fall or an accident curve rise steeply, conditions are obviously wrong, but what conditions may lead to better results is not directly indicated by the figures.

However, if a sufficient number of observations is made, the curves obtained permit comparisons between different factories and different conditions in the same factory that would be impossible to secure by the direct before-and-after method. In using the curves, no comparison of absolute figures is contemplated. Absolute figures of output are determined not merely by human capacity but by the efficiency of machines, the quality of material, the discipline exercised by the foreman and the general coordination of the factory staff. If compared directly, the hourly output of one factory against the hourly output of another factory, even on exactly the same process, might demonstrate nothing more than superior machines and superior foremen and superior materials in the one, as against the other. It would not show necessarily any superior schedule of hours. The curve method involves only a comparison of figures determined under the same conditions. The figures are yielded hour to hour in the same factory or section of the factory. Between the hours there can be no changes in factory organization or equipment. If the output curve in one factory drops heavily as work increases in length, while in another factory on the same operation the output curve continues steadily, then we may conclude that the latter factory has so arranged its hours and conditions of work that the workers do not suffer from undue fatigue at the end of their day.

I include a consideration of factory conditions advisedly, because the occurrence of fatigue, though running parallel with the length and intensity of activity, may yet be retarded or expedited in its course by different degrees of heat, damp, noise, dust, smell, comfort of posture, and so on, and as soon as accurate instruments are devised for grading each condition, its peculiar effect on the curves may be investigated just as scientifically as the effect of long hours, and the investigation will be just as important.